Anadolu Üniversitesi Sosyal Bilimler Dergisi | AÜSBD | Anadolu University Journal of Social Sciences

The Rebound Effect: Empirical Evidence from Turkey*

Rebound Etkisi: Ampirik Bir Örnek Türkiye

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Abstract

Energy and energy savings are still protecting its importance for both developed and developing countries. Energy saving is a method to reduce energy consumption in countries. Especially countries which have dependency on energy recently insist on energy efficiency. The aim of this study is to examine the theoretical and empirical literature on the rebound effect systematically and to test the impact of energy efficiency developments in Turkey on energy consumption empirically. In this study, Turkey's 1964-2009 annual time series data has been tested using ARDL (Auto-Regressive Distributed Lag) model. As a result of the empirical analysis in Turkey, it is concluded that, Rebound Effect which are results of energy efficiency, is not too significant size.

Keywords: *Energy Efficiency, Rebound Effect, ARDL Model, ECM*

Öz

Enerji ve enerji tasarrufu hem gelişmiş hem de gelişmekte olan ülkeler için önemini korumaktadır. Enerji tasarrufu ülkelerin enerji tüketimini azaltmada kullandığı bir yöntemdir. Özellikle enerji konusunda dışa bağımlı olan ülkeler son dönemler enerji verimliliği üzerinde durmaktadır. Bu çalışmanın amacı, Rebound Etkisi ile ilgili teorik ve ampirik literatürü sistemli olarak incelemek ve Türkiye'de enerji etkinliği gelişmelerinin enerji tüketimi üzerindeki etkisini ampirik olarak test etmektir. Çalışmada Türkiye'nin 1964-2009 dönemi yıllık zaman serisi verileri ARDL (otoregresif dağıtılmış gecikme) modeli kullanılarak test edilmiştir. Ampirik analiz sonucu, Türkiye'de enerji etkinliği gelişmeleri sonucu oluşan Rebound Etkisi'nin çok önemli boyutlarda olmadığı bulgusu elde edilmiştir.

Anahtar Kelimeler: *Enerji Verimliliği, Rebound Etkisi, ARDL Modeli, ECM*

Introduction

From the 80's to the present day, the effects of energy efficiency developments on energy consumption have been discussed. According to some energy economists, developments in energy efficiency would not be occurred on the expected level because of the mechanisms called "Rebound Effect". Those mechanisms depend on demand of the consumer for using the energy services, which became cheaper by means of energy efficiency, more and/or more often, or his ability to spend the savings, which were obtained from energy efficiency, for goods and services requiring more energy. It is being asserted that, energy efficiency developments to raise energy demand. However, some economists do not agree with this opinion and they assert that the rises based on energy efficiency developments, would not be in great numbers as expected.

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* This study called "Energy Efficiency and Rebound Effect of Residential Electricity Consumption in Turkey " is derived from the doctoral thesis which is accepted by Institute of Selcuk University Social Sciences, Department of Economics in 2012.

Energy and energy demand is an important subject for developing countries, especially for Turkey with its constantly growing economy, during the recent years. Because, Turkey is a country which highly depends on foreign energy resources and the main reason for the country's balance of payment's deficit is, its energy importation. Thus, determining the extent of the energy savings, derived from energy efficiency developments, is very important for Turkey.

Aim of this study is, testing the extent of "Rebound Effect" as considering Turkey's residential electricity consumptions during the time period 1964 – 2009. In the study, the data of time series has been analyzed as using ARDL co-integration approach.

Importance of this study is that, it is the first study systematically examining the rebound effect concept in Turkey. This study investigates the concept in terms of the empirical literature and empirically analyses it. The study consists of four chapters. In the second chapter, empirical literature on the rebound effect takes place. In the third chapter, the method and results of the study takes place and the fourth and final chapter summarizes the conclusion which is based on the empirical research.

The Literature on Rebound Effect

From the 1980's onwards, the relationship between household energy consumption and efficiency developments has attracted great attention of energy economists (Brookes, 2000, pp. 355; Greening et.al., 2000, pp. 389-390). Discussions have occurred on, whether energy efficiency developments are effective on decreasing energy consumption or not (Sorrell, 2007). Both independent studies and government policies assume that developing energy efficiency is the primary mechanism on decreasing energy demand. However, energy efficiency developments can't always be effective on decreasing energy demand, as presumed. "Rebound Effect" might occur and "energy savings" might decrease the amount of income (Herring and Sorrell, 2009, pp. 2). The concept of rebound effect is an umbrella term which is being used to name those mechanisms, decreasing the "energy savings", derived from the energy efficiency developments (Sorrell, 2007).

Today discussions of the rebound effect became a current issue again with the studies of Brookes (1979) and Khazzoom (1980). This effect has been examined in also these studies as follows: Khazzoom (1980), (1987), (1989); Khazzoom and Miller (1982); Lovins (1988); Brookes (1990), (1992), (1993), (2000); Saunders (1992), (2000a), (2000b); Howarth (1997) , Herring (1998), (1999), (2008); Herring and Roy (2006); Birol and Keppler (2000); Greening et. al. (2000); Schipper and Grubb (2000); Berkhout et. al., (2000); Binswanger (2001); Grepperud and Rasmussen (2004); Dimitropoulos and Sorrell (2006); Sorrell and Dimitropoulos (2005); Sorrell (2007); Sorrell and Herring (2009).

In the empirical studies of 1980's and 1990's examined mostly, the effects of efficient heating and air conditioning systems on energy usage. Transportation and housing sectors are two areas in which the empirical studies, focused on energy efficiency developments, conducted.

In Table 1, results of the studies related to the rebound effect and household heating, the rebound effect changes in between %10 and %25.

Some of the studies, related to "Direct Rebound Effect" in area heating, summarized in Table 2.

In all the studies summarized in Table 2, direct rebound effects are significant and lower than %100. In Table 3, the numbers of the studies related to the effect and the amounts of the rebound effect have been demonstrated.

Table 1. 1980-1990 Period of the Rebound Effect Studies Based on Singular-Service Model

Studies	Examples	Results
Khazzoom (1986)	Household electricity heating in Sacramento	%65
Dubin vd., (1986)	Includes 214 households participated in house area heating productivity	Between %8 and %13
Dinan (1987)	Examined 252 households insulated against cold weather.	Rebound Effect is Small but Statistically Significant
Hirst (1987)	Based on the evaluations of the Pacific North-West insulation against cold weather program	Between %5 and %25
Greene vd.,(1999)	Analyzed household surveys conducted in USA which are administered to three-year intervals of 1974-1994 period.	%20

Source: Binswanger, 2001, p. 124

Table 2. Estimations of Domestic Heating-Household Rebound Effect

Studies	Country	Rebound Effect
Khazoom (1986)	USA	%65
Dubin vd. (1986)	USA	%8-%13
Dinan (1987)	USA	Small but statistically significant
Hsueh ve Gerner (1993)	USA	For electricity %35, For Natural Gas %58
Schwartz and Taylor (1995)	USA	%1.4-%3.4 in long term
Hirst (1987)	USA	%5-%25
Nesbakken (2001)	Norway	%15-%55 (average %21)
Guertian et. al. (2003)	Canada	%29-%47 in long term

Source: Gonzalez, 2010, p. 2310

Table 3. Rebound Effect Measurements on Different Kinds of Hardware

Hardware	Rebound Size	Studies Conducted
Area Heating	%10-%30	26
Area Cooling	%0-%50	9
Water Heating	%10-%40	5
Residence Illuminating	%5-%12	4
Household Instruments	%0	2

Source: Gottron, 2001, p. 1

It can be seen that most of the studies, related to Rebound Effect, are focused on area heating and area cooling. As a result of examining the studies it can be seen that, for the studies related to area heating, the rebound effect values change in between %10 -%30 and for the ones related to area cooling, the rebound effect changes in between %0 and %50.

Table 4 summarizes the rebound effect estimations, for OECD member countries, of Sorrell and Dimitropoulos (2009).

According to results of the studies, in OECD member countries, long term Rebound Effect for household area heating and household area cooling, is average

Table 4. Estimations of Long Term Direct Rebound Effects for OECD Countries' Consumer Energy Services

Final Usage	Findings Value Interval (%)	Best Estimations (%)	Number of the Studies	Reliance Level
Area Heating	0.6-60	10-30	9	Mid.
Area Cooling	1-26	1-26	2	Low
Other Consumer Energy Services	0-41	<20	3	Low

Source: Sorrell, 2009, p. 38

of %30 and less than %30 (Sorrell, 2009: pp. 38). The empirical studies show that, the rebound effect is empirically real. Nevertheless, size of the effect changes due to the method and data used in the study. The studies, which are examined in this research paper, demonstrate that, the rebound effect changes between %5 and %50. This result means that, energy saving technologies would cause a reduction in the energy consumption but an important part of the energy saving potential would be lost just because of the increase of service demand.

Econometric Methodology and Results

Empirical Specification and Data

The residential electricity demand of Turkey was formulated by using equation which is based on Holtedahl and Joutz (2004).

$$LEC_t=a_0+a_1LP_t+a_2LYt+a_3LUr_t+\varepsilon_t \quad (3.1)$$

EC_t= Residential electricity consumption (kWh)

P_t= Residential reel electricity price index (TL/kWh)

Y_t = Real gross domestic product (1998 constant price in million TL)

Ur_t= Population (The total population living in cities with more than 1 million)

In study, the annual time series of Turkey was used for the period 1964-2009. The logarithm form was chosen of all series to make flexibility comment and to solve heteroscedasticity problems. EC_t represents total residential electricity consumption of Turkey (kWh), P_t represents residential reel electricity price index used in heating and lighting, (TL/Kwh), Y_t represents real gross domestic product, Ur_t represents the total population in Turkey living in cities with more than 1 million and ε_t represents error term. Substitution and complementary goods price were not employed because these data were not available in time series form for the period of the study.

Econometric Methodology and Results

The bounds test involves two stages. First one is to determine if there is a long run relationship or not among the variabes in Eqs. 3.1. The second stage is estimating the long and short run coefficients in Eq. 3.1.

According to KPSS unit root analysis, it indicates that only LRY (logarithm of real gross domestic product) data series is I(0), and the other variables,LEC (LEC_t represents total residential electricity consumption of Turkey), LRP (residential reel electricity price index used in heating and lighting) , LUR (the total population in Turkey living in cities with more than 1 million) are I(1).

ARDL Modeling

ARDL model was used to test whether there is a long run relationship or not among variables. We perefer to apply ARDL model as our variables are stationary at different levels. Some of them are stationary in the first level, and one of them is stationary in the level. For cointegration, ΔLEC was modelled as a Error-Correction Model.

$$\Delta LEC_t=a_o+a_1LEC_{t-1}+a_2LRP_{t-1}+a_3LRY_{t-1}+a_4LUR_{t-1}$$

$$+\sum_{i=1}^{m} a_{6i}\Delta LEC_{t-i}+\sum_{i=0}^{m} a_{7i}\Delta LRP_{t-i}+\sum_{i=0}^{m} a_{8i}\Delta LRY_{t-i}+\sum_{i=0}^{m} a_{9i}\Delta LUR_{t-i}+\varepsilon_t \quad (3.2)$$

Here, a_1, a_2, $a_3$and a_4 are long run parameters. Lagged values of ΔLEC_t and current and lagged values of ΔLRP, ΔLRY and ΔLUR were used to model short run dynamic structure.

Bound test is resorted to determine cointegration relationship between series. Standart F- statistic is applied to examined the null and alternative hypothesis. If the estimated F statistic is higher than the upper bound of the critical values, then the null hypothesis of no cointegration is rejected.

Calculated F statistic result is greater than 5% significant level value for the H_0 hypothesis, so null hypothesis can reject. That is, there is long run cointegration relationship between variables. Breush-Godfrey LM Test is employed to determine whether the model has autocorrelation or not.

Table 5. Bound Test Results

k	F-statistic	Significance level of 5% Critical Value	
		Lower Bound	Upper Bound
3	4.68	3.38	4.23

Notes: k represents independent variables number in the model .Critical values are taken from Pesaran etc. (2001:301) Table CI(iv).

Source: Pesaran et. al., 2001, p. 301

Table 6. Breush-Godfrey Autocorrelation LM Test

Fist.	0.496568	Prob(1,20)	0.4891*
Obs R^2	1.017530	Prob Ki-kare(1)	0.3131*
Fist.	0.118187	Prob(4,17)	0.9742*
Obs R^2	1.136366	Prob Ki-kare(4)	0.8885*

Note: * denotes statistical significance at %5

The results show that there is no autocorrelation according to 5% significant level.

ARDL Model Results and Long-Term Relationship of ARDL

After establishing that a long-run cointegration relationship existed, the model was estimated following ARDL specification

$$LEC_t=\beta_o+\sum_{i=1}^{m} b_{1i}LEC_{t-i}+\sum_{i=0}^{m} b_{2i}LRP_{t-i}+\sum_{i=0}^{m} b_{3i}LRY_{t-i}+\sum_{i=0}^{m} b_{4i}\,LUR_{t-i}+\beta_5 t+\nu_t \quad (3.3)$$

Table 7. Long-term Coefficients of ARDL Model

Variables	Coefficient	T Statistic	Prob.Value
LRP	-0.182	-2.021	0.0496**
LRY	2.010	4.270	0.0001*
LUR	1.016	4.364	0.0001*
c	-36.77	-4.477	0.0001*

Note: *, ** ,*** statistical significance at 1%, %5 and 10% respectively.

The ARDL model results based long run relationship between series are reported in Table 7.

In the study, we conclude that the coefficient of electricity price has negative sign and satistically significant. Also, coefficient of income and urbanization are positive and statistically significant. These results are consistent with theory and previuos studies. Estimating magnitude of Rebound Effect, price elasticity of demand can be used. The price elasticity of demand has negative sign and is statistically significant in the long run. The price elasticity is -0.182. The magnitude of the long run Rebound Effect is within the range of previous studies for other countries. Previous studies like Gottron (2001) and Sorrell (2009) who reported that Rebound Effect for residential heating is between 10% and 30% range.

ECT_{t-1} is error correction term is obtained from ARDL model. Error correction term is used to determine short run relationship. The negative and significant error correction term implies that short run instability will effect coming long run stability. The empirical results for the model in the short run are presented in Table 8.

Table 8. The Result of Error Correction Model Based ARDL Model

Regressor	Coefficient	T Statistics	Prob. Value
DLEC(-1)	-0.228	-1.870	0.0693***
DLEC(-2)	-0.336	-3.269	0.0025**
DLEC(-3)	-0.213	-2.073	0.0456**
DLRP	-0.060	-2.400	0.0220**
DLRY	0.724	10.827	0.0000**
DLUR	-1.449	-3.184	0.0031**
C	-0.015	-1.637	0.1107
ECT(-1)	-0.349	-5.991	0.0000**

Notes: *, ** ,*** statistical significance at 1%, %5, and 10% respectively and D denotes lag of variable

The error correction model denotes that the variables are statistically significant. In the short run elecricity price coefficient is negative and ıncome coefficient is pozitive. Both parameters have the expected signs and statistically significant. It means that in the short run the increase of electricity price diminish electricty consumption. On the other hand enhance income has positive effect on electricity consumption. The error correction parameter is negative and statistically significant. Hence, it implies that the short run instability will recover in the long run. As expected, the price elasticity of demand is much larger in the long run than the short run which suggests that price policies have stronger effects in the long time.

CUSUM ve CUSUMSQ Stability Tests

CUSUM ve CUSUMSQ tests examine whether long run parameters are stable or not. The stable estimated parameters indicate that the results of tests are reliable. The model was estimated by ordinary least squares and the residuals were subjected to the CUSUM and CUSUMSQ test.

The curves obtained from CUSUM ve CUSUMQ statistics are between critical value which represent stability at the %5 significance level. The results show that the estimated parameter of model are stable.

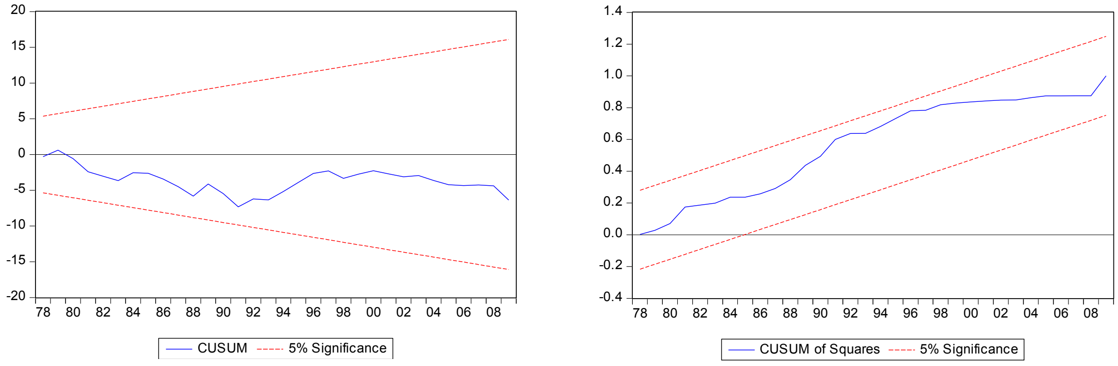

Figure 1. CUSUM Square Graph and CUSUMSQ Square Graph

Conclusion

The theoretical and empirical studies related to Rebound Effect demonstrated that, the amount of the effect can be different according to the method used, the industry, energy services, time factor and the level of development. Thus, in the studies related to Rebound Effect, some important details like the method used, the energy service definitions like heating, illuminating and transportation, the distinctions like firm, industry and economy, time dimensions as short, mid and long terms and development level of the studied country, must be clearly stated.

In those studies about the effect, different amounts of Rebound Effect have been attained in different countries and industries. The findings demonstrate that the effect is generally in between %5 and %50. Rebound Effect is strongly under the effect of the substitution differences in between all the factors (energy, capital, labor, raw materials) and those differences have been changing in time. It must be taken in consideration that, the energy efficient technologies, which are expanding factors other than energy, can possibly cause additional Rebound Effect(s).

In this research paper, electricity price elasticity is estimated, as using annual data for the period 1964-2009 for Turkey. As a result of this research, it is found that, long term electricity price is inelastic and its value is -0.18. According to this result, it is found that, Rebound Effect in the housing sector in Turkey, is not too high. In Turkey, the rebound effect in household electricity consumption is %18.

According to the evaluations, which are based on price elasticity and following Khazoom (1980)'s study, %18 of the energy savings derived from energy efficiency developments, will be taken back as a result of the changes in consumer behaviors. Thus, the energy saving which is resulted from the energy efficiency developments, will be %82.

The concept of "Rebound Effect" is closely related to the environment and climate changes. This effect became an important component of the environmental policies, depending on the rise of the energy consumption. It is necessary that, the rebound effect to be taken in consideration in the practices, related to the climate changes and environment. Developments in energy efficiency can cause additional negative environmental effects because, with more energy usage, comes more toxic substances and transportation. Thus, some important problems like potential risks and noise become current issues. In such a case, a dislocation of "environmental rebound" from the economic area to the environmental area can be observed.

Despite the rebound effect is ingrained in related, foreign theoretical and empirical literature, it still needs to be developed in some areas. The amount of the effect should be analyzed, especially, in terms of the developing countries and as taking in consideration some important parameters like industries, transportation capabilities, housing sectors and general economies of these countries. For instance, it is known that rising industry level energy efficiency decreases micro level energy usage but its effect on macro level energy usage, is still controversial. Practical computations of the rebound effect in especially the climate change policies are needed in the related literature.

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